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Indicators for assessing changing landscape character of cultural landscapes in Flanders (Belgium)

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ABSTRACT

The increasing pace and scale of landscape change initiated a renewed interest in cultural and heritage values of the landscape. Efforts are made in inventorying, monitoring, and evaluating landscapes, needed for developing management and conservation plans, and also new concepts emerged. Landscape character became a new paradigm, as well as time depth and landscape change trajectory or path. Also, the use of landscape indicators for describing character and assessing changes has been widely tested. In Flanders, the rich landscape diversity is degrading rapidly due to extreme urban pressure and severe fragmentation by transport infrastructures. In this study a series of spatial data layers was used to describe and map the transformation of landscape character. Historical topographical maps and orthophotomaps from different periods were used to define landscape character types, which were mapped as polygons in a GIS. Map overlaying allowed analyzing the time depth and landscape constancy. The landscape character types were used as patches for the spatial and structural analysis and defining indicators of character change. A selection of class and landscape-based landscape metrics were used as such indicators, as well as the openness of the landscape. This selection was based upon the presumed relationship between the indicator and perceivable (visual) properties relating to landscape character. The landscape indicators express change very differently and several indicators are necessary to assess changes in the landscape character.

Introduction

Contemporary landscapes change rapidly and continuously, in particular in highly urbanized areas (Antrop, 2003a). Vos and Klijn (2000) recognized two main trends: intensification and extensification. These changes cause a significant loss of the diversity and identity of cultural landscapes (Stanners and Bourdeau, 1995; Council of Europe, 2000) and thus also a loss of sense of place (Pedroli, 2000). Bürgi et al. (2004) recognise four major challenges for researching landscape-change: studying processes in relation to spatial patterns, extrapolating results in space and time, linking data of different qualities, and considering culture as a driver of landscape change. Landscapes possess an important heritage value, which is considered to be increasingly threatened (Lowenthal, 1997; Austad, 2000; Holdaway and Smart, 2001; Lörzing, 2001; Claval, 2005). As a result, programs were initiated for inventorying and assessing landscapes and for monitoring changes, not only at a national level (Swanwick, 2002; Antrop, 2003a; Dramstad and Sogge, 2003; Pinto-Correia, 2004; Wrbka et al., 2004), but also at a Pan-European scale (Meeus, 1995; Vervloet and Spek, 2003; Mücher et al., 2006). Stimulated by the European Landscape Convention, landscape character is emerging as a new concept. Landscape character is defined as 'a distinct, recognisable and consistent pattern of elements in the landscape that makes one landscape different from another, rather than better or worse', and also 'Essentially, Landscape Character is that which makes an area unique' (Swanwick, 2002). Particular combinations of physical landscape components (geology, landform, soils, vegetation) and anthropogenic elements and components (land use, field patterns and human settlement) create the character, which makes different landscapes distinct from each other and gives each its particular sense of place (Swanwick, 2004). Thus, landscape character is an expression of the holistic nature of the landscape (Antrop, 2003b; Jessel, 2006). Landscape character assessment was performed first in England. Guidelines for landscape character assessment were developed by the Countryside Agency and are now widely practiced also outside the UK (Swanwick, 2004; Wascher, 2005; Nogué and Sala, 2006; Van Eetvelde et al., 2006; Kim and Pauleit, 2007). Sometimes, landscape character refers to traditional generic landscape types such as openfield, enclosed landscapes or bocage, commons, etc. When historic and archaeological features are important, the approach is called Historic Landscape Characterisation (Fairclough, 2003; Rippon, 2004). Many changes of the traditional landscapes and the emergence of new landscapes related to urbanisation, transportation, recreation, and tourism, broadened the concept of landscape

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character to include all types of landscapes, as proposed by the European Landscape Convention.

A growing need for landscape inventorying, assessment, and monitoring demands also the development of landscape indicator that's are useful in policy (Bastian and Röder, 1998; Haines-Young, 1999; Dramstad and Sogge, 2003; Fry et al., 2004). For policy-makers, many important questions relate to evaluate the impact of policy measures and their effect on the landscape change (Parris, 2004).

The focus is not only on conservation and protection of natural and cultural capital, but also on sustainable development (Haines-Young, 2000), spatial planning, and landscape management (Selman, 2006). Core questions are: what kind of development is acceptable where? How much change can be tolerated? When does the landscape character change in an irreversible manner? Haines-Young and Chopping (1996) argued that structural changes between past and present landscapes can be quantified by means of landscape indices. Dramstad et al. (2006) showed that landscape heterogeneity is related to landscape values such as biodiversity, cultural heritage and human appreciation. The size and shape of open landscape reflect the scale of the perceived landscape. When linking the structural characteristics of a landscape, described by landscape metrics, with everyday perceptual properties common to all observers, metrics represent a potential for indicator-based planning and management (Dramstad et al., 2001). Uuemaa et al. (2007) used landscape metrics as indicator for river water quality assessment. Haines-Young and Potschin (2005) proposed a typology of landscape indicators and indicators for landscape character.

In the Flanders region (Belgium), a framework for landscape assessment was developed to be used in landscape management, planning, and heritage conservation. This assessment resulted in an inventory (atlas) of the relics of the traditional landscapes (Hofkens and Roosens, 2001). In Flanders, the traditional landscapes refer to the landscapes before the Second World War, i.e. before the important changes caused by urbanisation and industrialisation of the countryside that wiped out the ancient landscape structures (Antrop, 1997). However, time series of historical maps since the end of the 18th century showed also important changes before the Second World War that transformed profoundly the character of the rural landscape several times. Hence, landscape relics cannot be defined as stable and fossilised ancient landscapes, but areas characterised by a specific time depth and landscape path through history.

The first objective of this paper is to define landscape character types for different time periods and define their time depth and landscape trajectory by analysing different historical periods between 1775 and 2000 for a selected relic zone from the Flemish landscape atlas. The second objective is to analyze the sensitivity of quantitative landscape indicators that aim to describe landscape character and landscape changes.

Study area and materials

The landscape atlas of Flanders

The landscape atlas of Flanders is an inventory of the relics of the traditional landscapes of Flanders made between 1995 and 2001 and reviewed in 2005. As this initiative fitted very well within the general measures as proposed in the European Landscape Convention, the Flemish government adopted the landscape atlas as an important reference document for its landscape management and heritage conservation policy (Hofkens and Roosens, 2001; Antrop et al., 2004; Antrop and Van Eetvelde, 2007). The identification of the traditional landscapes of Flanders was the first attempt to map traditional landscape character types at a small scale (1:100,000). This classification formed the baseline for this assessment of the current condition of the landscape.

The time reference for the identification of the relics was given by the historical map of de Ferraris, realized between 1770 and 1780 for military purposes during the Austrian period. This map is the first detailed and systematic map (scale 1:11,500), and it covers almost the entire territory of the later state of Belgium. It represents in detail the landscape at the end of the Ancien Régime in the late 18th century, just before the important changes induced by the French and Industrial revolution (Antrop, 2003b). This map is commonly used in Flanders as a reference in historical and landscape research, but also in applied policy-oriented research in forestry, nature conservation, and in landscape conservation.

The current situation of the relics of Flanders was given by the orthophotomaps of 1990 at a scale of 1:10,000. This was the base to define and select the landscape relics. Landscape structures and features that referred to the historical maps before the Second World War and which were still legible on the orthophotomaps, were selected as relics and mapped in a GIS. Several types of relics were defined. Relic zones are areas that conserved the main historical landscape structures formed by settlement and field patterns, which are characteristic for the traditional landscape. Anchor places group complexes of very different features related by a unique historic development (ensembles), but which can be atypical for the traditional landscape they are located in. Examples are estate parks or designed historical landscapes. Fig. 1 shows an overview of the relic zones in the landscape atlas. They occupy 39% of the total area in Flanders, while anchor places cover 16.3%. The severe fragmentation by urbanisation and dense transportation networks is also expressed in the large number of relic patches as well as their size average: 515 relic zones (average size 1029 ha) and 381 anchor places (average size 580 ha) were mapped (Antrop, 2003b).

Study area and materials

The study area for this paper is one relic zone of 52 km^2 between the cities of Ghent and Bruges (Fig. 1). The area is intersected by a motorway with access, which makes the area sensitive to urban and recreational development. As a result, the relic zone was affected by successive abrupt changes in landscape character, which all left an imprint on the landscape and are still very legible today (Daels, 1995). Fig. 2 gives a time series of historical maps used, illustrating the profound changes of the landscape character since the end of the 18th century. Historical maps are very useful to define landscape character types because they provide, depending on the quality and properties, information of the landscape character of the different time periods, because they represent topography, land use, field pattern, settlement pattern, and infrastructure (Vuorela et al., 2002). The oldest map (A) is the historic map of de Ferraris dating from 1775 and showing the characteristic heath-land of the commons. The topographic map of Vander Maelen of 1850 (B) is the first topographic map of the independent state Belgium and illustrates the first reforestations in the 19^{th} century. The topographic map of the Military Geographical Institute (C) represents the situation just before the First World War and was revised in 1940, i.e. just before the Second World War. The topographic map of 1950 gives the situation after the Second World War and just before the boom of the suburbanisation in the 1960s. Since the 1990s, orthophotomaps (D and E) give more or less regular updates every 5 years.

Several derived thematic maps were also available. These included a vector-GIS database of the evolution of the forests since the 18th century using the available topographical maps (former Institute for Forestry and Game Management (IBW)) and an inven-

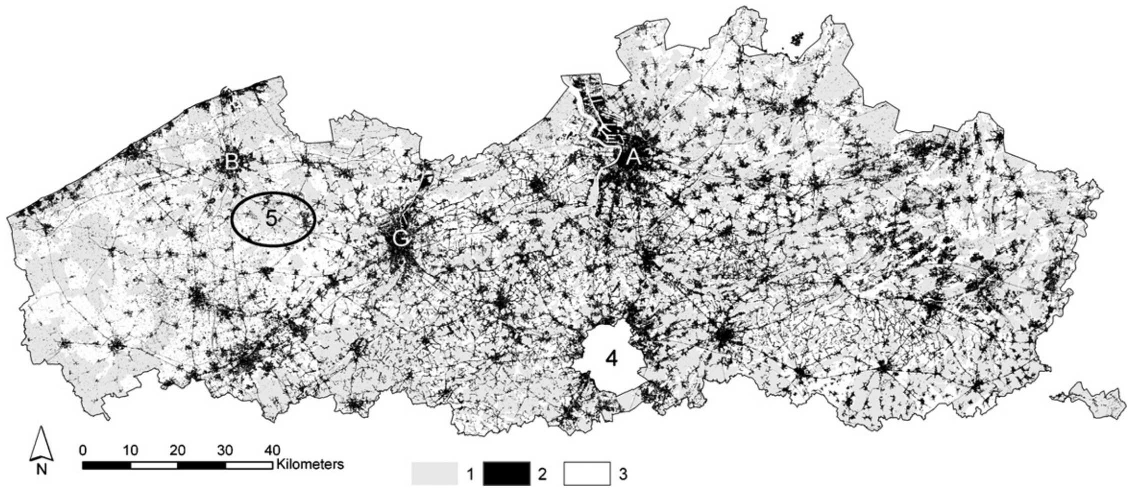

Fig. 1. Landscape characterisation of Flanders, based upon the Landscape Atlas, and location of the study area. (1) Relic zones of traditional landscapes, (2) urbanized and industrialized areas, (3) transformed rural landscapes, (4) Brussels region not mapped, (5) case study area. Main cities: (A) Antwerp, (G) Ghent, (B) Bruges.

tory of the built-up land based upon the orthophotomap of 1990 (Province of Eastern Flanders).

Table 1 gives the properties of the data used to assess the landscape character types and to calculate the landscape metrics.

Methods

The first step consisted of the transformation and standardisation of the significant landscape features on the different maps (Table 1) in a common classification of landscape character types with a unified legend covering the years 1775, 1850, 1910, 1990, and 2000. These landscape character types are based on the dominant land cover and land use interpreted in the historical context and meaning (Table 2). They were mapped as polygons in a vector-based GIS. For georeferencing on a common basis to allow overlaying and spatial analysis, the most detailed and accurate map was used, which was the colour orthophotomap of 1/10,000 of 2000. The thematic database of the forests and the inventory of the built-up land were also integrated as GIS-themes.

In the second step, landscape metrics were used to describe the landscape composition and configuration of the relic zone, which forms the extent of the landscape under study. The grain was determined by the minimal mapable units of the landscape types mapped as vector polygons and considered as patches for the landscape pattern analysis. Landscape metrics describe spatial patterns which are the result of landscape forming processes. The composition metrics indicates the presence and variety of types, without taking into account their spatial arrangement; configuration indicates the spatial arrangement, position or orientation of patches (Botequilha Leitao et al., 2006). In this case, as patches are formed by landscape character types, landscape metrics describe their spatial properties and also the overall character of the landscape considered, i.e. the relic zone. Landscape metrics were calculated for each time period and selected based on their expected relationship with character properties that can be perceived and experienced by humans (Table 3). All the landscape metrics were calculated on vector themes using Patch Analyst in ArcView 3.x (Elkie et al., 1999).

The size and shape of the individual patches were calculated. The corrected perimeter area (CPA) shape index was used according to Farina (1998):

$$\mathrm{CPA} = \frac{(0.282P)}{A^{0.5}}$$

Based on the patches, following landscape metrics were calculated per the different landscape character types and for each time period: number of patches (NP), proportion of type (P_LCT),

Table 1
Datasets used to define the landscape character types.

Datasets	Date	Original scale
Historic map of de Ferraris	1775	1/25,000
Topographic map of Vander Maelen	1850	1/20,000
Topographic map Military Geographic Institute	1884–1933	1/20,000
Orthophoto map Eurosense	1990	1/10,000
Orthophoto map NGI	1997–2000	1/10,000
Thematic maps: evolution of forests (The Institute for Forestry and Game Management)	2000	1/10,000
Thematic map: inventory build-up land (Province of Eastern Flanders)	1990	1/10,000

Table 2
Generic landscape character types for the time series analysis.

ID	Landscape character type	Description
1	Commons and outfields	Former common land (heath-land) used for grazing, with sand pits and ponds, and some outfields. Traditionally open landscape.
2	Planted woodland	Enclosure of former common land and outfields, planted with mainly conifers and some deciduous forest.
3	Infields and intensive cropland	Former infields and new reclaimed cropland of the former outfields and common land, with up-scaling of the field size and geometrical patterns.
4	Meadows and hay-fields	Small areas of permanent grassland in valleys and depressions.
5	Settlements and urban sprawl	Historic villages and hamlets with later expansion of urbanisation along the access roads
6	Designed landscapes	Estate parks and new straight exploitation roads and alleys.
7	Services, businesses and infrastructure	Services and businesses outside village centres, mainly along main roads.
8	Rural land affected by recreation	Fragmented agricultural land and forest by second residences and week-end houses.

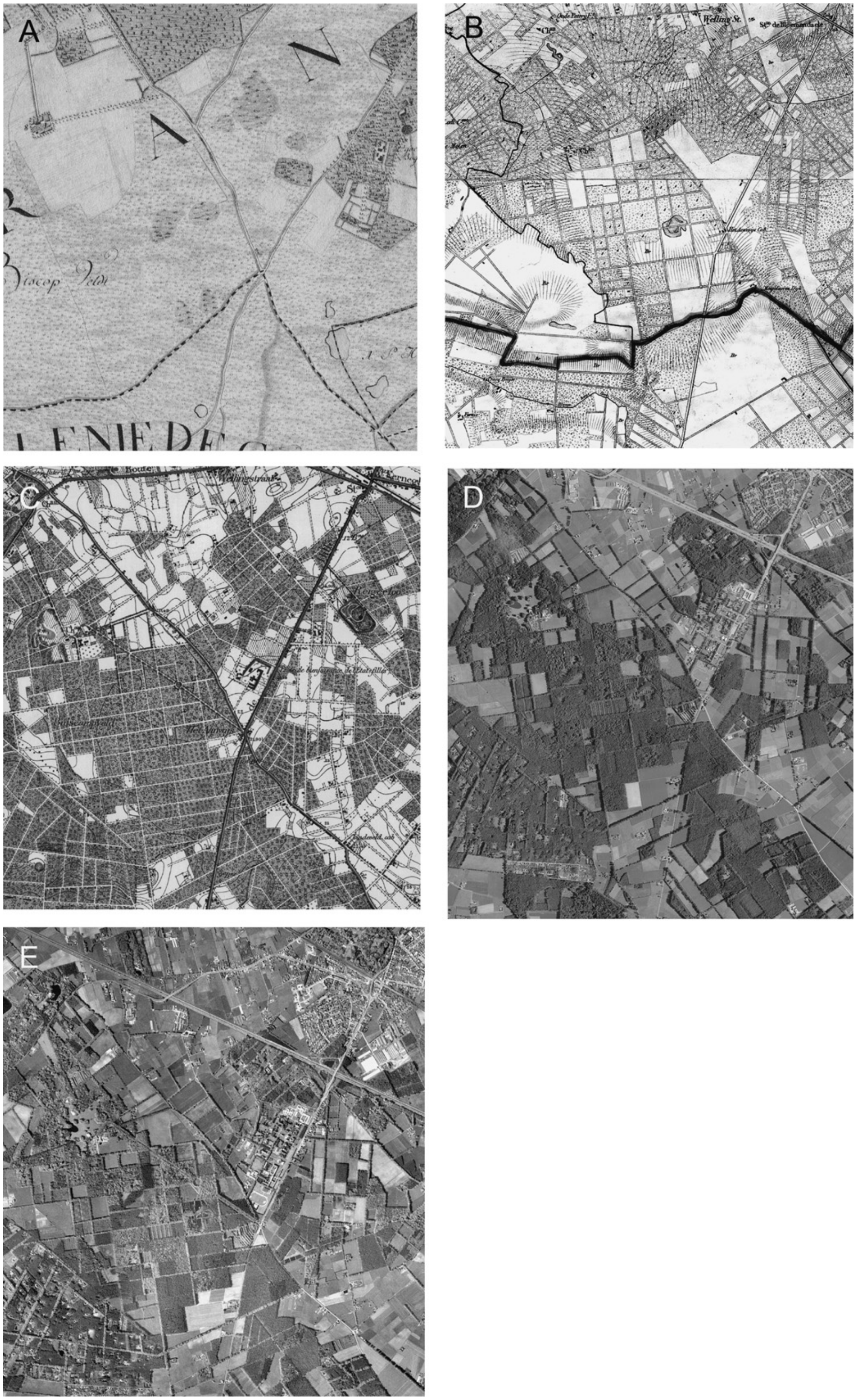

Fig. 2. Examples of the change of landscape character in the central part of the study area: (A) at the time of the de Ferraris map in 1775, (B) the map of Vander Maelen in 1850, (C) the maps of MGI, 1911, (D) on the orthophotomap of 1990, (E) on the orthophotomap of 2000.

Table 3
Landscape metrics as expected indicators of landscape character.

Acronym	Landscape metric	Class	Landscape	Indicator for landscape character
P_LCT	Proportion of landscape character type (%)		√	Dominance of character types, diversity, types that become exceptional.
NP	Number of patches	√	√	Degree of spatial fragmentation of character type or landscape; complexity.
AREA_MN	Mean patch area	√	√	Geometric complexity, variation, landscape scale.
PD	Patch density	√	√	Landscape scale, size of landscape elements.
CPA	Mean shape index	√	√	Spatial complexity; artificial (geometric forms) versus irregular natural forms.
PR	Patch richness		√	Landscape character type diversity
H	Landscape heterogeneity		√	Order versus chaos, heterogeneity; variation versus monotony.
O	Openness		√	Wide views versus enclosed spaces.

mean patch area (AREA_MN), patch density (PD), and mean CPA shape index (CPA). For the formulae see McGarigal et al. (2002). Landscape-based metrics were landscape diversity or heterogeneity, expressed by the information-entropy of Shannon (H), and openness of the landscape (O). For the entire relic zone, also the mean and variance of the CPA-index were calculated.

The number of patches gives an indication for the fragmentation of the area. The landscape heterogeneity (H) was expressed as the Shannon diversity based on the summed information entropy (Shannon, 1948; Stöcker and Bergmann, 1978; Antrop and Van Eetvelde, 2000), as follows:

$$H = -\sum p_i \ln p_i$$

where p_i is the proportion of the total area occupied by landscape character type i.

The heterogeneity H combines the diversity of landscape character types and the frequency of occurrence of the different landscape character types.

In addition, also an indicator related to the openness (O) of the landscape was calculated, which was expressed as the percentage of the area occupied by landscape character types offering a wide open view, such as commons (heath-land) and outfields; infields and intensive cropland; meadows/hay land.

Finally, the transitions between the landscape character types were determined between the successive time periods, using overlaying of the successive map series, as shown in Fig. 3. Thus, temporal characteristics are indicated also in a metrical form. The time depth of each, of the contemporary patches was defined, as well as the frequency of change. These were visualized in maps of time depth and landscape constancy (Fig. 5).

Results

Fig. 3 shows the final result of the remapped, standardized, and generalised landscape character types. Fig. 4 and Table 4A give the evolution of the landscape character in the relic zone based on the proportional occurrence of the different landscape character types for each period. So, the situation in 1775 is characterized by the traditional late commons and outfields, occupying 55% of the total area. The land enclosure and reforestation can be recognized on the topographical maps between 1850 and 1910, where 54% of the total area of the relic zone consists of planted woodland. The emergence of the urbanisation of the rural landscape becomes important since 1990 (5%).

Tables 4 and 5 give the landscape metrics for the different time periods. Commons (heath-land) and outfields occurred only in 1775 with 7 patches while in 1850 only three patches remained. The number of patches of settlement and urban sprawl increased steadily from 37 in 1775 to 635 in 2000 (Table 4B). The overall number of patches increased from 120 to 869; and slowed down

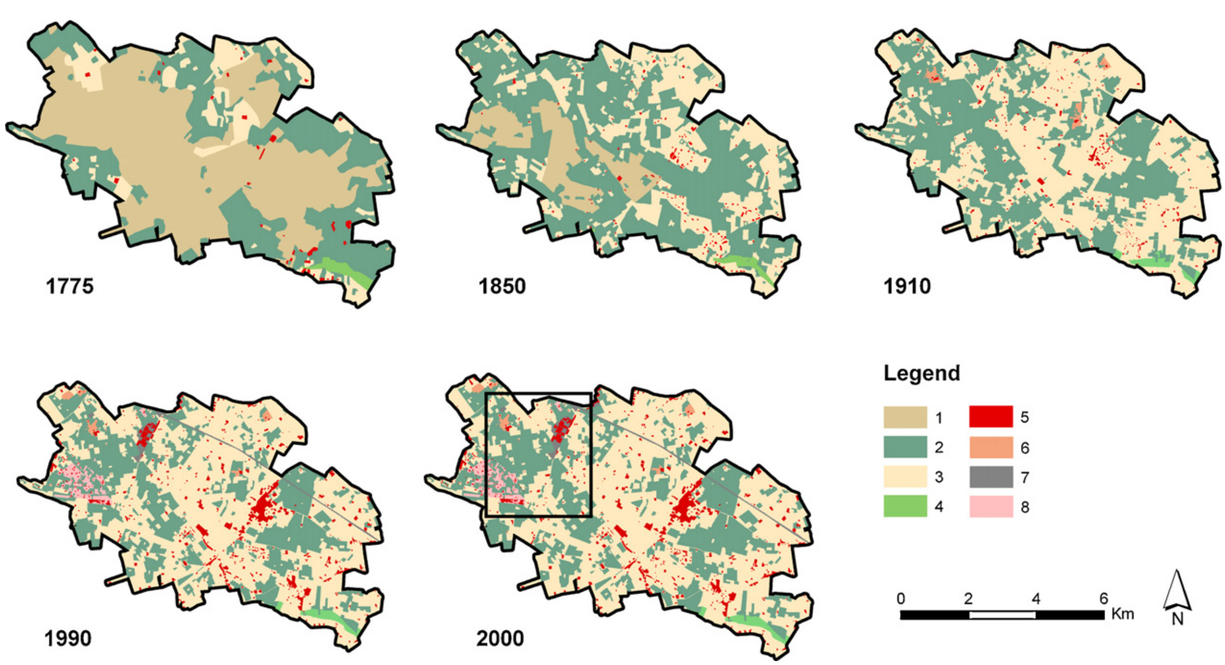

Fig. 3. Evolution of the landscape in the study area between 1775 and 2000 (with delineation of the extent of Fig. 2): (1) commons and outfields, (2) planted woodland, (3) infields and intensive cropland, (4) meadows and hay-fields, (5) settlements and urban sprawl, (6) designed landscapes, (7) services, businesses and infrastructure, (8) rural land affected by recreation.

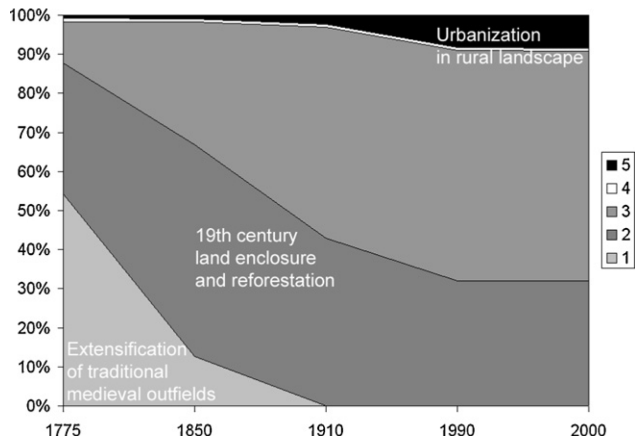

Fig. 4. Proportion of landscape types: (1) commons and outfields, (2) planted woodland, (3) infields and intensive agricultural land, (4) meadow- and hay land, (5) settlements and urban sprawl; designed landscapes; services and commerce with associated infrastructures; agricultural land and forest affected by second homes and recreation.

in the second half of the 20th century (Table 5). The mean patch area shows different trajectories for each landscape character type (Table 4C). The average size of the commons and outfield patches decreased from 4.01 km^2 to 2.19 km^2, and disappeared completely at the beginning of the 20th century. Land enclosure and reforestation was important in the mid-19th century with large patches of planted woodland, indicated by an average size of 0.56 km^2. The characteristic regular spatial structure of these land reforms is not reflected in a change op de CPA-shape index (Table 4E). The replanted woods became fragmented in 2000, reducing the mean patch area to 0.14 km^2 and the patch density from 0.70 patches per km^2 in 1775 to 2.36 in 2000. In the same period, patches of infields and intensive cropland became aggregated and larger indicated by an increase of their average size from 0.14 km^2 in 1910 to 0.37 km^2 in 2000. The mean size of the patches of settlement and urban sprawl decreased during the 19th century and has been slightly increasing since then (Table 4C). This indicates that many new small sites were built during the 19th century and larger lots were used afterwards. However, it must be noted here that part of the increase might be caused by a difference in digitalisation of the data sources: the orthophotomaps of 2000 were used tot digitize the foot print of every building visible in the image. The agricultural land and forest was affected by suburbanisation in the form of second residences and recreation after the Second World War in the western part of the study area.

Only the patch density showed significant variation. The landscape became more fragmented and fine grained, but the recent up-scaling of different land use types, larger agricultural fields in particular, showed a slight slowing down of the fragmentation process (Table 4D). The mean shape index of the patches remained almost constant (Table 4E).

Landscape heterogeneity showed little variation, only a slight decrease of entropy (from 1.04 to 0.84) could be noticed from 1850 to 1910, indicating that the landscape became more homogeneous and lost diversity (Table 5). This was mainly due to the disappearance of the commons and outfields, causing a decrease in the number of landscape character types and so of the richness. In the beginning of the 20th century, planted woodland and infields an intensive cropland was almost equally dominant types. The increase of landscape heterogeneity between 1910 and 2000 (from 0.84 to 1.01), indicates the emergence of a new more diverse landscape, introducing new landscapes character types, such as designed landscapes and estate parks, the increase of urban sprawl and of services, businesses and related infrastructure, and the urbanisation of the countryside by second residences and recreation facilities.

The wide open landscape patches of the commons and outfields lasted until the 18th century and decreased due to the systematic enclosure and reforestation in the 19th century. The overall openness of the relic zone decreased from 66% to 45% during the plantation of the new forests. Afterwards, due to the extension and up-scaling up agriculture, the openness gradually increased again up to 60% in 2000 (Table 5).

The mapping of the time depth of the patches shows that only 10% of the area still contains landscape structures that existed already in the 18th century, and 29% of the areas refer to the late 18th-early 19th century. 35% represent late 19th-early 20th century landscape character types and 26% of the relic zone dates from the end of the 20th century (Fig. 5). Half of the study area changed only once and only 4% changed between three or more time periods (Fig. 5).

Discussion

For this relic zone, three moments of change can be recognized between 1775 and 2000, creating a succession of landscapes with very distinct character. Changing political, economical and societal context caused shifts in land use and so landscape pattern creating a different landscape character. Thus different periods can be defined as suggested also by Bürgi and Russell (2001). In a first stage, the heath-land commons were planted with forest, which made the outfields disappear completely and made the landscape more enclosed increasing its patchiness. Second, large areas became reclaimed as cropland; infields gradually became dominant and fragmented. In a third stage, new landscape character types due to urbanisation and development of infrastructures gradually emerge and occupy less than 10% of the area in the relic zone today. The exact moments or periods these changes were initiated cannot de determined with certainty because of the temporal resolution of the maps series. However, the nature of the change can be linked to descriptions in other data sources. Some changes are the result of new legislations; others are related to planning and design. Lambin et al. (2001) argued that most are the result of agricultural intensification and urbanisation. Increased accessibility is structural driving force due to the proximity of infrastructure, exits, station, railway (Schneeberger et al., 2007) and has local influence in the study area. Many small changes are the result from more random processes of autonomous development (Antrop, 1998).

Haase et al. (2007) showed that studying land use changes by using historical periods gives the opportunity to indicate how land use affects the performance of landscape functions. They also argued that changes caused by land use gives an indication for the resulting state of the landscape and changes of landscape character. Different methods for standardizing historical maps and imagery have been proposed by Petit and Lambin (2002), Vuorela and Toivonen (2003), Käyhkö and Skånes (2006), Haase et al. (2007) and Hamre et al. (2007). Petit and Lambin (2002) showed that map generalisation could improve the integration of data for change detection.

Times series are useful to predict future general trend, provided that the political and economical conditions do not change (Haase et al., 2007). Time depth and knowledge of the historical landscape development are important for a retrospective (long-term) landscape monitoring. Studying historical change of the landscape as a continuous process is impossible since only static map representations for discrete time periods are available (Muir, 2003). Using fixed time periods makes it more difficult to define the different and often unique trajectories followed by the individual

Table 4
Time series of class-based metrics for the landscape character types: proportion of landscape character type (%) (A), number of patches NP (B), mean patch area (km²) (C), patch density (patches/km²) (D), mean CPA shape index—CV% (E).

ID	Landscape character type	1775	1850	1910	1990	2000
(A)						
1	Commons and outfields	55	13	0	0	0
2	Planted woodland	34	54	43	32	32
3	Infields and intensive cropland	11	31	54	59	59
4	Meadows and hay-fields	1	1	1	1	1
5	Settlements and urban sprawl	0	1	1	5	5
6	Designed landscapes	0	0	1	1	1
7	Services, businesses and infrastructure	0	0	0	1	1
8	Rural land affected by recreation	0	0	0	2	2
(B)						
1	Commons and outfields	7	3	0	0	0
2	Planted woodland	36	50	103	121	122
3	Infields and intensive cropland	39	96	209	81	83
4	Meadows and hay-fields	1	2	3	2	2
5	Settlements and urban sprawl	37	169	329	495	635
6	Designed landscapes	0	0	4	5	5
7	Services, businesses and infrastructure	0	0	0	4	8
8	Rural land affected by recreation	0	0	0	14	14
(C)						
1	Commons and outfields	4.013	2.190	0	0	0
2	Planted woodland	0.480	0.561	0.216	0.137	0.135
3	Infields and intensive cropland	0.140	0.169	0.133	0.377	0.367
4	Meadows and hay-fields	0.556	0.224	0.159	0.216	0.216
5	Settlements and urban sprawl	0.010	0.003	0.002	0.005	0.004
6	Designed landscapes	0	0	0.093	0.058	0.058
7	Services, businesses and infrastructure	0	0	0	0.145	0.075
8	Rural land affected by recreation	0	0	0	0.066	0.060
(D)						
1	Commons and outfields	0.14	0.06	0.00	0.00	0.00
2	Planted woodland	0.70	0.97	1.99	2.34	2.36
3	Infields and intensive cropland	0.76	185	4.04	1.56	1.60
4	Meadows and hay-fields	0.02	0.04	0.10	0.04	0.04
5	Settlements and urban sprawl	0.72	3.27	6.36	9.56	12.27
6	Designed landscapes	0.00	0.00	0.08	0.10	0.10
7	Services, businesses and infrastructure	0.00	0.00	0.00	0.08	0.15
8	Rural land affected by recreation	0.00	0.00	0.00	0.27	0.27
(E)						
1	Commons and outfields	2.34–39	2.47–08	–	–	–
2	Planted woodland	1.66–41	1.69–81	1.77–48	1.67–42	1.69–42
3	Infields and intensive cropland	1.62–30	1.68–50	1.80–80	2.02–90	2.00–91
4	Meadows and hay-fields	1.98–00	1.77–50	1.91–35	2.16–25	2.16–25
5	Settlements and urban sprawl	1.20–11	1.19–05	1.23–12	1.25–15	1.30–37
6	Designed landscapes	–	–	2.58–18	1.78–29	1.78–29
7	Services, businesses and infrastructure	–	–	–	4.23–49	2.94–67
8	Rural land affected by recreation	–	–	–	1.99–79	2.13–84

CV%: coefficient of variation.

patches (Vuorela and Toivonen, 2003). Nevertheless, because of some shortcomings of these historical topographical maps, their use in landscape change analysis needs special attention. Topographical maps since the 18th century have sufficient resolution and quality (geometry and content) for medium-scale studies (Rippon, 2004). Older maps are rarely accurate enough and should be used as supplementary source (Haase et al., 2007). Maps differ in survey techniques, details, accuracy, production, map content. Not all historical maps possess detailed legends and metadata. Often the legend categories are different defined between surveys and objects are differently mapped and represented accordingly, making a unified legend sometimes difficult. The transformation of map categories into generic landscape types is a common technique in historical landscape analysis (Rippon, 2004), allowing easier comparison between time periods. Also integrating the time layers as themes in a GIS becomes simpler.

Table 5
Landscape-based landscape metrics.

	1775	1850	1910	1990	2000
Total number of patches	120	320	650	722	869
Mean patch density	2.34	6.18	12.26	13.95	16.79
Mean CPA shape index	1.44	1.43	1.43	1.44	1.45
Patch richness	5	5	5	7	7
Heterogeneity (entropy H)	1.02	1.04	0.84	1.01	1.01
% openness	66	45	55	60	60

Whether landscape metrics describe landscape character is also dependent on the definition of landscape character. Landscape character types and areas are often generic and nominal. However, they are represented on categorical maps as patches that can be described by landscape metrics. Banko et al. (2003) demonstrated that landscape types are optimal spatial units for defining landscape indicators. Such a 'broad-brush' approach offers the possibility to set a framework covering the whole area of study at a landscape scale level, which allows subsequent more detailed studies. This is also used in the Historic Landscape Characterisation approach in England (Fairclough et al., 2002; Rippon, 2004).

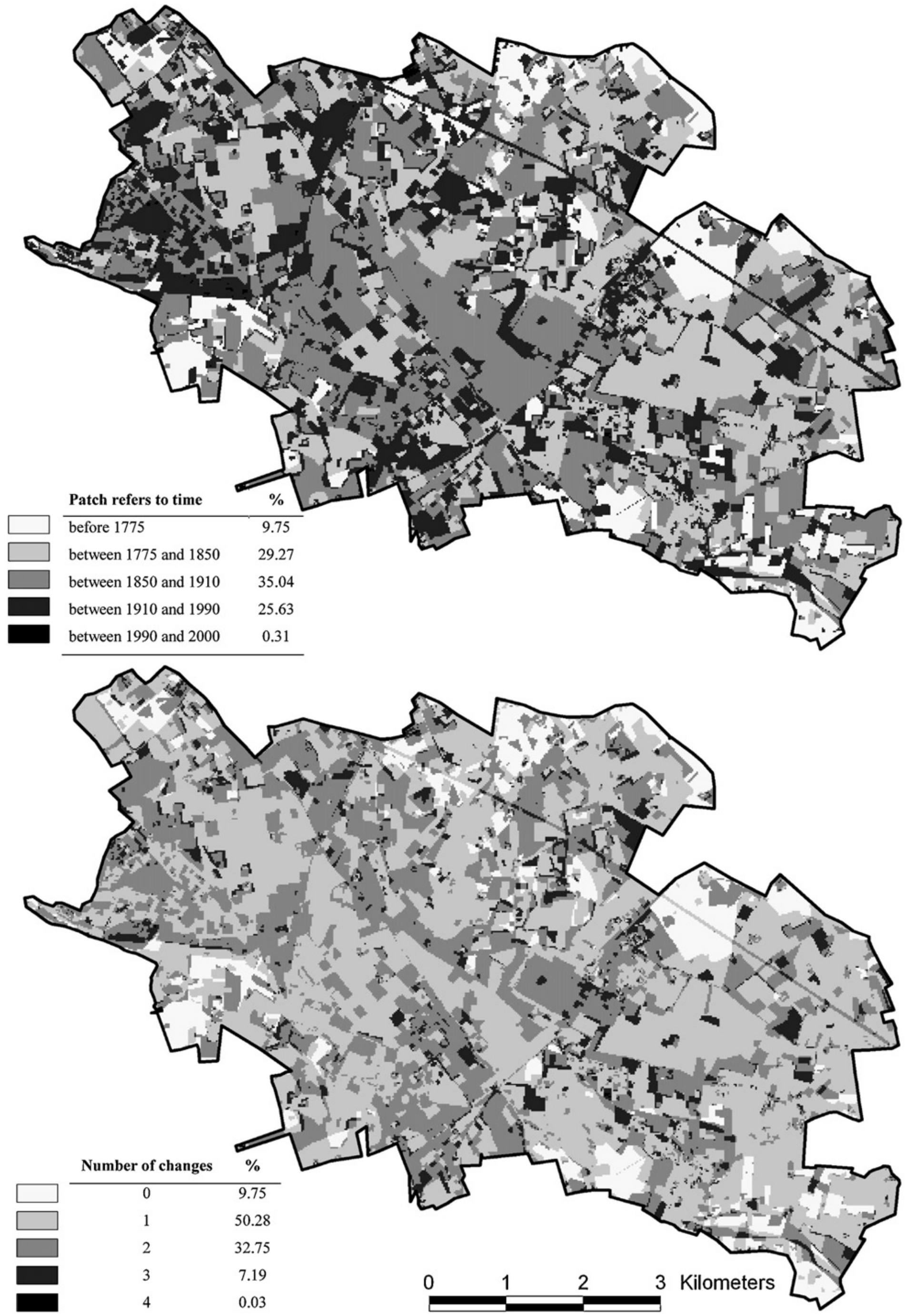

Fig. 5. Time depth of the landscape in the study area: (A) Time depth: (1) before 1775, (2) between 1775 and 1850, (3) between 1850 and 1910, (4) between 1910 and 1990, (5) between 1990 and 2000; (B) Frequency of changes in landscape character type between 1775 and 2000.

The value of landscape metrics is the ability to compare landscape configurations, for example at different times and under different scenarios (Gustafson, 1998), but under strict preconditions (e.g. Haines-Young and Chopping, 1996; Li and Wu, 2007). Botequilha Leitão and Ahern (2002) proposed a core set of landscape metrics useful in sustainable landscape planning, which are related to ecological processes. However, they argued that the use of a single landscape metric is insufficient to characterize the landscape, which is also clearly demonstrated in this study. Many landscape metrics are correlated but the knowledge of the relationships between landscape structure and functions is still insufficient for building useful models (Haines-Young and Chopping, 1996; Botequilha Leitão and Ahern, 2002; Li and Wu, 2004; Li and Wu, 2007). To interpret landscape metrics and use them as a landscape indicator, the relations must be established between its numerical value, the spatial pattern and the processes behind (Li and Wu, 2004). Landscape metrics cannot be tested for statistical significance (Li and Wu, 2007). In the case of landscape character change, the causal processes are to found in changing societal and economical needs, which are often related to demographic processes and policy decisions. Consequently, landscape indicators rather describe the nature and magnitude of landscape character change.

The number of patches varies in this case with the impact of urbanisation, causing more fragmentation and more patches, and with the up-scaling of agriculture reducing the number of parcels and homogenising the land use. The interpretation of an evolution of a landscape metric often demands additional information that cannot be derived directly from maps or photographs. For example, the decrease of the average size of the built-up patches during the 19th century and the slight increase afterwards indicates that first many new but small lots were built and that later larger lots were used. The recent increase of landscape heterogeneity, is the result of an increase of the number landscape types, thus of landscape diversity or richness (Antrop and Van Eetvelde, 2000).

The effect of positional error and the occurrence of sliver polygons as a result of map overlaying, can affect the results of landscape metrics (Palang et al., 1998). Petit and Lambin (2002) used landscape metrics to assess the uncertainty of changes resulting from this kind of map comparison. In this study combining thematic maps showed non-systematic positional errors. Most errors consisted of translations and did not affect the shape and size of the patches significantly.

The actual landscape structure is the final result of a long recording, a palimpsest of the past history (Muir, 2000; Claval, 2005). Time depth is an important landscape characteristic meaningful for planners and policy-makers. For example, in Flanders, categories such as "historical permanent woodland", "historical permanent grassland" and "historical permanent cropland" are legally defined as sensitive zones in nature and heritage protection. Also, knowing the time depth helps in defining landscape quality objectives as stated by the European Landscape Convention (Fairclough, 2003). Landscape constancy mapping identifies stable areas, which can be ecologically important, as past landscape structure is relevant for the occurrence of present day species (Burel, 1993).

Conclusions

Landscape character types can be defined easily as holistic units using a wide variety of cartographic sources such as historical maps and orthophotomaps. The landscape character types are meaningful in analysing the time depth and landscape change trajectory. Landscape metrics can be used as indicators of some properties of the changing landscape character. The indicators are selected based on their presumed relationship with landscape character properties that are perceivable by humans in the landscape. Multiple indicators are needed to assess different aspects of landscape character change.

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